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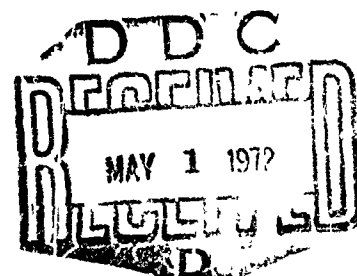
ADMIXTURES FOR CONCRETE

by

Bryant Mather



June 1965



U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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FOREWORD

This manuscript was prepared at the request of the Secretary-Treasurer of the Japan Chapter of the American Concrete Institute in order that he might have some text that could be translated into Japanese that would represent the principal features of a discussion that was to be presented at a meeting of that organization held in Tokyo on 5 February 1965. Essentially the same information was included in discussions given at meetings of the American Concrete Institute and chapters of the American Concrete Institute in Monterrey, Mexico, in March 1964; at Newark, New Jersey, in April 1964; in Detroit, Michigan, and Buffalo, New York, in July 1964; in Pittsburgh, Pennsylvania, in September 1964; in Boston, Massachusetts, in November 1964; in Berkeley, California, Eugene, Oregon, and Los Angeles, California, in January 1965; in Honolulu, Hawaii, Tokyo, Japan, Oklahoma City, Oklahoma, and Arlington, Texas, in February 1965, and at meetings sponsored by the American Society of Civil Engineers in Jackson, Mississippi, in January 1965 and in Vicksburg, Mississippi, in June 1965.

The manuscript was approved for presentation and publication by the Office, Chief of Engineers, by first indorsement dated 17 June 1965 to a letter dated 19 May 1965, subject, "Approval of Paper for Presentation and Publication."

Some of the data referred to were developed as part of the Engineering Studies Program, Item ES 601, "Research in Mass Concrete," conducted at the Concrete Division, U. S. Army Engineer Waterways Experiment Station, under the direction of Mr. Thomas B. Kennedy.

Director of the Waterways Experiment Station during the preparation of this paper was Colonel John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

Admixtures for Concrete

by Bryant Mather*

The American Concrete Institute -- a voluntary association of more than 12,000 people interested in concrete -- renders services to its members through a variety of activities. The best known of these is its publications. An important feature of its publications program is the issuance of the reports of its technical committees, of which there are now more than sixty.

One of these committees that I have had the opportunity to serve on is Committee 212 on Admixtures, which was organized in 1943 "to gather, correlate, and report information on the effect of various admixtures on the properties of concrete." I went to work for the Corps of Engineers in 1941, which was just about the time that the Corps of Engineers and others were beginning to appreciate the significance of air entrainment as a means of beneficially affecting the properties of concrete, especially with respect to frost resistance. So 1943 was a time when a major development in the desirable modification of the properties of concrete through the use of admixtures was taking place. Committee 212 published its first report in 1944. Its second report came in 1954, and its latest report was in the ACI Journal for November 1963 -- reprints can be obtained from ACI Headquarters for \$1 per copy.

The question is sometimes asked, "What is the attitude of ACI toward admixtures for concrete?" A similar question is rather more often asked

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concerning the attitude of the Portland Cement Association toward admixtures. Mr. Hubert Woodr, then Director of Research for PCA, speaking at the February 1964 Convention of the National Ready-Mixed Concrete Association, said: "The impression seems to be fairly widespread that the PCA is against admixtures of every kind. This is simply not so. For nearly two decades we have been advocating air-entrained concrete...air-entraining admixtures are an indispensable part of modern concrete technology...There are circumstances under which accelerators or retarders or water reducers or other admixtures may usefully be employed...We do not recommend indiscriminate use of admixtures...which renders the concrete less than adequate for its intended purpose...Use without adequate accuracy in batching, without adequate understanding of its use and function... will lead to inadequate concrete."

These comments do not differ in intent from those of ACI Committee 212.

Its report after defining an admixtures as: "a material other than water, aggregates, and hydraulic cement that is used as an ingredient of concrete and is added to the batch immediately before or during mixing," adds: "An admixture is used to modify the properties of concrete in such a way as to make it more suitable for the work at hand...An admixture should be employed only after appropriate evaluation of its effects..."

It has been estimated that last year three billion tons of concrete were produced, one ton for every living human being. Most of this concrete is serving and will continue to serve the purposes for which it was produced. Some has already been found unsatisfactory; more will suffer early distress. In these cases the properties of the concrete were inadequate. In a greater

number of cases the concrete has properties that it does not need to the degree that they have been provided, and their presence has served no purpose other than to raise the initial cost higher than it needed to be.

It thus follows that, not only is there a very large volume of concrete produced but there is a very wide range of desirable properties that concretes should possess. To return to the 212 report, "An admixture is used to modify the properties of the concrete in such a way as to make it more suitable for the work at hand."

What are the properties of concrete that may be modified by the use of admixtures? I can think of no property of concrete that can not be modified by the use of an admixture. The 212 report lists 18 "more important" purposes for which admixtures may be used which include modifying: workability, rate of strength gain, ultimate strength, setting time, heat evolution, bleeding, resistance to frost action, volume change, permeability, unit weight, bond to steel, color, and ability to kill fungi, bacteria, or insects. Not mentioned in this list is cost -- often a major property beneficially modified by use of an admixture.

The report classifies admixtures in 15 categories: accelerators; water reducers and set controllers; grouting admixtures; air-entraining admixtures; air-detaining admixtures; gas-forming admixtures; expansion-producing admixtures, finely divided mineral admixtures; dampproofers and permeability reducers; bonding admixtures; chemical admixtures to reduce alkali-aggregate ~~reaction~~ ^{expansion}; corrosion inhibitors; fungicidal, germicidal, and insecticidal admixtures; flocculating admixtures; and coloring admixtures. In short -- decide what property you wish to modify and in which

direction you wish to change it, and probably there is an admixture that can be employed to modify that property in that direction.

In our laboratory in the past few years we have had reason to try to produce concretes of rather severely modified properties; we wanted concrete with an ultimate strength of only a few hundred psi -- for shock absorption; we wanted concrete of at least 10,000 psi ultimate compressive strength -- for use in constructing arches; we wanted concrete of minimal heat evolution -- for massive dams; we wanted concrete both with 10,000 psi strength and high unit weight -- for biological shielding against radiation; we wanted concrete of extreme frost resistance -- for hydraulic structures in extremely severe climates; we wanted concrete of minimum cost -- to compete with earth for dams. In every case the concrete that was developed to meet the need was concrete containing one or more classes of admixtures as described in the ACI 212 report.

I have 10 lantern slides that illustrate some of the topics to which I have referred. The first shows some concrete specimens at our severe natural weathering exposure station on the Atlantic Coast near the border of Canada. Here, in the winter as the tide falls, the specimens emerge and quickly freeze without having a chance to dry. This photograph shows some after one winter -- those with entrained air are in good condition; those without are not. The second slide is a view of a sand, water, air-entraining admixture system photographed through a microscope to show the air bubbles that impart the frost resistance in air-entrained concrete. The third shows some laboratory results in which frost resistance is plotted as durability factor against compressive strength. Without

entrained air, even though the strength may be great when the concrete is frozen, the frost resistance is very low. With air-entrainment a good degree of frost resistance is present even with quite low strength concrete. The fourth slide shows a first effort at developing a relation between air content, water content, cement content, and strength. Since, as air is added to a concrete mixture, water must be reduced if workability is to be kept the same at equal cement content, and since strength varies as water-cement ratio, there should be, for any set of materials, some level of cement content below which the reduction of water content as air content is raised will lower the water-cement ratio enough per unit of air added so that the strength will actually increase as air content is increased. For these materials it is indicated that this point is about 300 lb of cement per cubic yard.

The second group of admixtures with which our laboratory has worked extensively is pozzolans. The fifth slide is a photomicrograph of fly ash -- the pozzolan now used in most Corps of Engineers mass concrete -- by means of which very considerable reduction of cost has been achieved. The sixth shows some relations of pozzolan-portland cement mixtures and heat evolution. A gram of a portland cement-pozzolan mixture consisting of equal portions will have somewhat greater heat evolution than that of the cement portion alone, but very much less than a gram of cement. The seventh slide shows the localities in the United States at which deterioration of concrete due to the expansive consequences of the chemical reaction between alkalies and soluble silica in aggregates have been found. The eighth slide shows laboratory test data on a variety of materials, mostly pozzolans, in which it is seen

that the use of any of these -- in an appropriate amount -- as an admixture can reduce the expansion that would otherwise be expected by 75% -- or to 1/4 of that if the admixture were not used.

The ninth slide shows data on some experimental concrete that illustrate the potentialities of multiple admixture usage. By use of air entrainment, in this case largely to reduce water content and cement content by beneficially affecting workability, and by use of a large amount of pozzolan, it was possible to produce satisfactory lean mass concrete containing only 94 lb of portland cement per cubic yard. In addition, by the use of either of several water-reducing admixtures, the water content could be lowered further.

I end -- with my last slide -- by repeating Mr. Woods's warning, "We do not recommend indiscriminate use of admixtures which render the concrete less than adequate for its intended purpose."